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Final Report to the Department of Energy

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Comparison of currents measured by OSCR*, an experimental current meter and drifting floats† at a site in the Irish Sea

Final Report to the Department of Energy
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INTRODUCTION

There is at present a clearly recognized need for better knowledge of the current structure in the near-surface region. One requirement arises in the context of environmental forces acting on offshore structures. This in turn is linked with the need for a better understanding of the physical processes involving momentum and heat transfer - and hence with our ability to model them for prediction purposes.

As yet, however, relatively few observations have been reported in this region, due mainly to the difficulties in making them successfully. For moored sensors, the problems encountered include the inability of small surface buoys to survive severe conditions, quite apart from the innate difficulties in measuring a relatively small mean flow in the presence of a generally much larger three dimensional oscillatory flow. With the development within the past few years of instruments with greatly improved linearity and directional response, some attention is now being given to the development of suitable moorings. Work at IOS has suggested that for measurement within the uppermost metre or two, a sensor attached to a wave-slope follower may provide the best approach, while at depths which are greater - but still too shallow to permit use of subsurface buoyancy - a freely suspended current meter is probably the only feasible technique to use. Very close to the surface moored measurements are further complicated by the disturbance to the flow caused by the buoy hull itself. An experimental sensor has recently been devised in order to overcome this limitation (Multilevel Vector Averaging Electromagnetic Current Meter) and is described briefly in Appendix 1, Figs. 3(a) and (b).

Lagrangian techniques represent another approach to near-surface current measurements, in which a float is used to tag a parcel of water, and the rate of displacement of the float yields the current, measured in a moving frame of reference. For the resolution of scales of motion greater than, say, 10 km, satellite based systems of position fixing are adequate, but at smaller scales, acoustic positioning techniques may be used. Observation of such scales generally requires the use of a ship, thereby incurring appreciable cost. Nevertheless the need for intercomparison is such that Lagrangian methods make a very useful contribution to the solution of the problem (Collar and Griffiths, 1982).

Given the difficulties and expense of making large scale observations with moored instruments and floats the interest shown in remote techniques such as CODAR (Barrick et al.) is not surprising. The recent development of the Ocean Surface Current Radar (OSCR) at the Rutherford-Appleton Laboratory (King et al., 1984), which derives current estimates from Bragg scattering at 27 MHz from the sea surface is therefore welcome. The information so provided is essentially complementary to that obtained from moored current meters: on the one hand OSCR rapidly provides area coverage within a range of several tens of kilometres of the installation, in a way that would be prohibitively expensive by any other means. On the other hand a moored current sensor can resolve a range of scales of motion which are effectively averaged out by the width of the OSCR beam and the length of a range bin. Nevertheless, intercomparisons between the different techniques can be made - and the need for these cannot be overstressed. They represent the only way in which any new technique will gain acceptance by potential users.

For these reasons the opportunity was taken to include OSCR in an intercomparison experiment carried out by IOS in the Irish Sea. The main objectives of the experiment may be summarised as:

(1) Intercomparison of data from surface moored instruments and bottom moored instruments with a view to evaluating the suitability of the moorings and new types of sensor for measurement of current profiles in shallow seas.

(2) Comparison of data obtained from the OSCR with concurrent data from the experimental surface current sensor in order to make a preliminary assessment of the techniques, and to gain experience which might provide a sound basis for any further comparative studies.

(3) Comparison of these data with the displacement rates of drifting floats in order to help in these assessments.

This report addresses the second objective, comparison between the OSCR and the experimental MVAECM. Although technically not covered by the contract, comparison with some of the early float data (objective 3) has proved valuable and these results are also included. Full comparison must, however, await the working up of the complete float data set.

EXPERIMENT DETAILS

The experiment was carried out in the western Irish Sea near 54°N, 5°45'W. The area (fig. 1) was chosen for several reasons, but principally because tidal streams are weak and the effect of waves on near-surface moorings might be expected to assume greater importance; also float tracking is considerably more manageable in such conditions - and has a greater likelihood of success than, for example, at a more exposed site. At the time of year chosen the water in the area is generally well mixed although in April a strong, seasonal frontal system develops, which persists until the autumn. Among other practical considerations, the presence of land within 12-15 miles was thought likely to provide a suitable site for OSCR. At sea the major disadvantage of the area proved to be the level of fishing activity, although this part of the experiment was not affected thereby. However it may be an important factor to be considered in planning any future work of a similar nature.

The dispositions of the moorings are shown in fig. 2. Several moorings incorporated transponders and these provided the basic navigation for the ship during the float tracking experiment. The system is based on the measurement of the ranges of a drifting float by interrogation firstly from the ship, whose position is determined relative to the network of fixed transponders and secondly from a remotely triggered moored interrogator. Directional orientation of the fixed transponder network was achieved by taking bearing measurements on surface buoy markers using the ship's gyro compass. The technique as applied to the tracking of surface floats is described more fully in Collar, 1978.

Although the OSCR functioned well throughout the experiment, and a substantial data set was obtained from the floats, the MVAECM record was restricted in length to about 16 hours by damage incurred in the overturning of the buoy during severe weather in the early part of the experiment. Weather conditions had a substantial impact on the experiment (Appendix 2 - summary cruise report).

It should be remarked that the mooring had survived several periods of storm conditions in an earlier test mooring off the Scottish coast near Oban. The reasons for failure in this case probably lie in the confused nature of the seas which are much more likely to cause overturning of surface buoys than the highly directional seas encountered in the Firth of Lorne. Although the data set is considerably shorter than hoped for, it is nonetheless valuable in being obtained during the onset of the storm.

Float tracking could not be commenced until two days later, by which time conditions were calm and remained so for much of the duration of the experiment.

RESULTS

(a) MVAECM and OSCR

Time series plots for levels 1 and 4 (10 cm and 40 cm depth respectively) are shown in fig. 4. These illustrate the high degree of coherence obtained between outputs at different levels (levels 2 and 3 are omitted only to simplify the presentation). The noisy nature of the data has yet to be fully explored but it results from a combination of small scale variability, some mooring motion, and a small residual contribution from wave orbital velocities and sensor motion. Note that the mean current is significantly greater at 40 cm depth than at 10 cm depth: agreement in direction is good, however. The origin of this current shear - data from levels 2 and 3 are consistent in this respect - is not at present clear. The more obvious instrumental sources have been eliminated: work on this aspect will continue.

Comparison with the time series obtained from OSCR is made in fig. 5. As used in this part of the experiment, OSCR produced hourly values of the radial current component within two cells in the range interval 23.7-28.5 km from the transmitter. The average was constructed over approximately 6 minutes. For comparison we have taken a mean of 5 × 56 second samples of the MVAECM data; this greatly reduces the high frequency variance and results in a remarkably smooth series given the surface conditions prevailing at the time (figs. 6 & 7).

Agreement between 40 cm currents measured by the MVAECM and currents obtained from the OSCR is at times very good, although large differences are apparent between 0500 and 0800 on the 23rd March when the resolved current at all levels by the MVAECM fell to nearly zero. The minimum level recorded by OSCR exceeds 8 cm/s.

(b) OSCR and floats

The comparison of the output of OSCR with some early float data is shown in fig. 8 (this represents only a small fraction of the complete data set). Position fixes were taken generally every half hour and each symbol represents the rate of float displacement between adjacent fix times, resolved along the OSCR beam direction. Floats took the form of cylindrical tubes, 0.1 m in dia. × 1.7 m long. Drogues were of the cruciform type and measured 0.8 m × 1.8 m. Throughout the period shown, comparisons were made with drogues centred at 0.5 m depth. Only a few cm of each float appeared above the water surface and errors in float speed caused by wind forcing were estimated to be insignificant. Significant wave height decreased steadily throughout the day (fig. 6) and the sea surface was calm during the latter part of the comparison. During the early part of the day only one float was in the water, while tracking procedures were being established. Later, three 0.5 m floats were deployed (a fourth at 1 m is not shown), one being recovered before nightfall.

The scatter in the float data results from a combination of position fix errors - estimated roughly as 3 cm/s r.m.s. - and real spatial differences in the flow. Some indication of this is given by the differences in float tracks (fig. 9), but further analysis of the complete data set will be required before this can be properly established.

DISCUSSION AND CONCLUSION

Given the disparate nature of the observing systems, the agreement shown in these limited observations is for much of the time remarkably good. Clearly, the differences that do emerge need further investigation, particularly as these arose in storm conditions. At this stage, before the complete data set has been worked up it would be unwise to draw firm conclusions. But the encouraging results thus far obtained strongly recommend further comparative studies in a range of current and wave conditions, using two OSCRs so as to define the total current vector.

The present observations do not reveal much about the nature of the current profile very close to the sea surface. There is uncertainty concerning the way in which surface wave speed is modified in the presence of a sheared current - and hence in the nature of the depth average implicit in the h.f. radar data. According to the simple model of Stewart and Joy (1975), for example, h.f. radar yields a measure of the average current of $O[2k]^{-1}$ where k is the water wavenumber. For the present system this is ~0.5 m. A depth average of the data produced by the MVAECM over this range, however weighted, would produce currents well below those measured by OSCR. As yet we have found no instrumental shortcomings or inaccuracies in calibration which could explain the observed reduction in measured current close to the surface. The differences in currents measured at each level seem to be related to the current magnitude rather than to surface conditions, and this suggests that rectification of orbital motion is not an important contributory factor. The present float data are unlikely to aid the interpretation of the current meter data set, for the vertical dimension of the smallest drogue is ~0.8 m, and it would be difficult to reduce this significantly, while maintaining the effectiveness of the drogue.

Finally, there are two related areas which will need to be examined ahead of any further comparative observations at sea. Firstly, a need exists for a rugged surface buoy which can withstand the worst conditions without overturning. The present buoy and sensor were of an experimental nature and were not originally intended for use in exposed conditions. Secondly, any further work would almost certainly be carried out in a much stronger tidal regime than that encountered here: as yet there is little experience in designing compliant moorings suited to near surface current measurement in fast tidal streams.

APPENDIX 1

Multilevel Vector Averaging Electromagnetic Current Meter (MVAECM)

The experimental electromagnetic sensor arrangement is shown in fig. 3(a) and (b). A pair of annular coils provide the vertical magnetic field, and potentials generated in the water by the flow through the field are sensed by orthogonal pairs of electrodes at four levels, 0.1, 0.2, 0.3, 0.4 m below the instantaneous sea surface. Buoyancy is provided by a thin inflated ring at the surface. The current sensor operates continuously, the output from each axis being sampled at ~2 Hz. The outputs are combined with compass heading to provide components resolved in East and North directions and these are averaged at present over 56.25 seconds so as to reduce the residual wave orbital contribution to the flow. Measurements are made, in effect, simultaneously at all four levels.

The sensor is supported by compliant tethers upstream of a parent buoy, which is steered into oncoming flow by a fin (fig. 3(b)). The whole system had been found to work well in trials conducted off the Scottish coast near Oban prior to these measurements. The trials encompassed several storms.

APPENDIX 2

(a) Main OSCR activities

7th February	Site inspection and selection, St John's Point, Northern Ireland.
18th March	OSCR arrived on site.
22nd March	Trials completed. Continuous operation commenced 13.51.
30th March	Operation ceased 20.06.
2nd April	Site cleared.

(b) Cruise summary report

RRS Frederick Russell sailed from Falmouth at 12.00 on 19th March. A brief stop was made en route in order to test acoustic releases for the moorings and the mooring site was reached at 17.00 on 20th. Following an echosounder depth survey and it having been established that the sea bed was adequately firm, deployment of the meteorological buoy and waverider commenced at 19.00 hrs. During this period, also, initial contact was established with the OSCR shore site via the maritime VHF channels - a link which was subsequently found to be essential to the conduct of the experiment. Following the deployment of the first two moorings, a CTD cast was made in order to test for stratification in the water.

Mooring deployments commenced again at 06.45 on the 21st and were completed by 13.30. An acoustic range test was carried out on the transponder incorporated in mooring F and course was then set for Holyhead, berthing at 23.00, in order to take on more equipment and exchange two members of the scientific party.

The site was reached again at 11.30 on the morning of the 22nd and work resumed on the laying of moorings; this was completed at 22.20.

Throughout this initial phase the weather had been very calm, but during the night of the 23rd it began to deteriorate. By 08.00 gusts up to 50 knots were being recorded on the ship and work on surveying-in the transponder network was clearly impossible. Conditions were at their worst in the early afternoon, with heavy, confused seas and winds gusting to 60 knots; the Waverider record subsequently produced a maximum significant wave height of 4.7 metres at a mean period of 6.8 seconds.

By the following morning (25th) conditions were greatly improved and the moorings were inspected for damage. The MVAECM buoy had overturned and the sensor itself had been smashed. Two other annular surface buoys had also overturned, and as discovered later, had sustained minor internal damage. The MVAECM mooring was recovered; two other surface buoys were also recovered, but their moorings were otherwise left intact since they carried the transponder beacons. By 13.30 work had started on surveying-in the transponder network. The bearings of surface buoys marking transponder moorings were established using the ship's gyro compass. Thereafter courses were steamed between moorings while interrogating continously so as to determine the separations of the fixed transponders. The first of a regular series of CTD dips was also made.

By 05.00 on the 25th the weather was again worsening rapidly and at 09.00 the ship left the site to shelter in the lee of the Isle of Man, arriving at midday. Conditions improved later in the day and the ship returned to the site by 22.30. With moorings apparently still in place a start was now made on the float tracking, the first float being deployed shortly before 01.00 on 26th, and being recovered at 08.05. For the next few days operations fell into a regular pattern, various combinations of floats (drogued at 0.5, 1, 3 and 13 m) being deployed close to the array and recovered once they had drifted too far away. Some subsidiary experiments were also carried out using drift cards. Conditions were generally light, although during the night of 29th/30th the wind freshened and produced some evidence of vertical shear in the float tracks.

The float tracking experiment ended at 07.30 on 30th March and the more* vulnerable surface moorings were recovered prior to making a short port call at Holyhead that evening. The larger surface buoys were successfully recovered on return to the site at 06.00 on 31st March, in spite of poor weather, and the site was cleared by 17.00 hrs. The ship then steamed to Liverpool Bay where two moorings were laid in preparation for a subsequent experiment with OSCR. Falmouth was reached at approximately 16.00 on 2nd April.

*During the course of the experiment some problems had arisen from the level of fishing activity and loss of surface floats or damage was sustained by three moorings. One surface current buoy disappeared - apparently as a result of an encounter with a ship's propeller - and was found on a beach in Eire a few days later.

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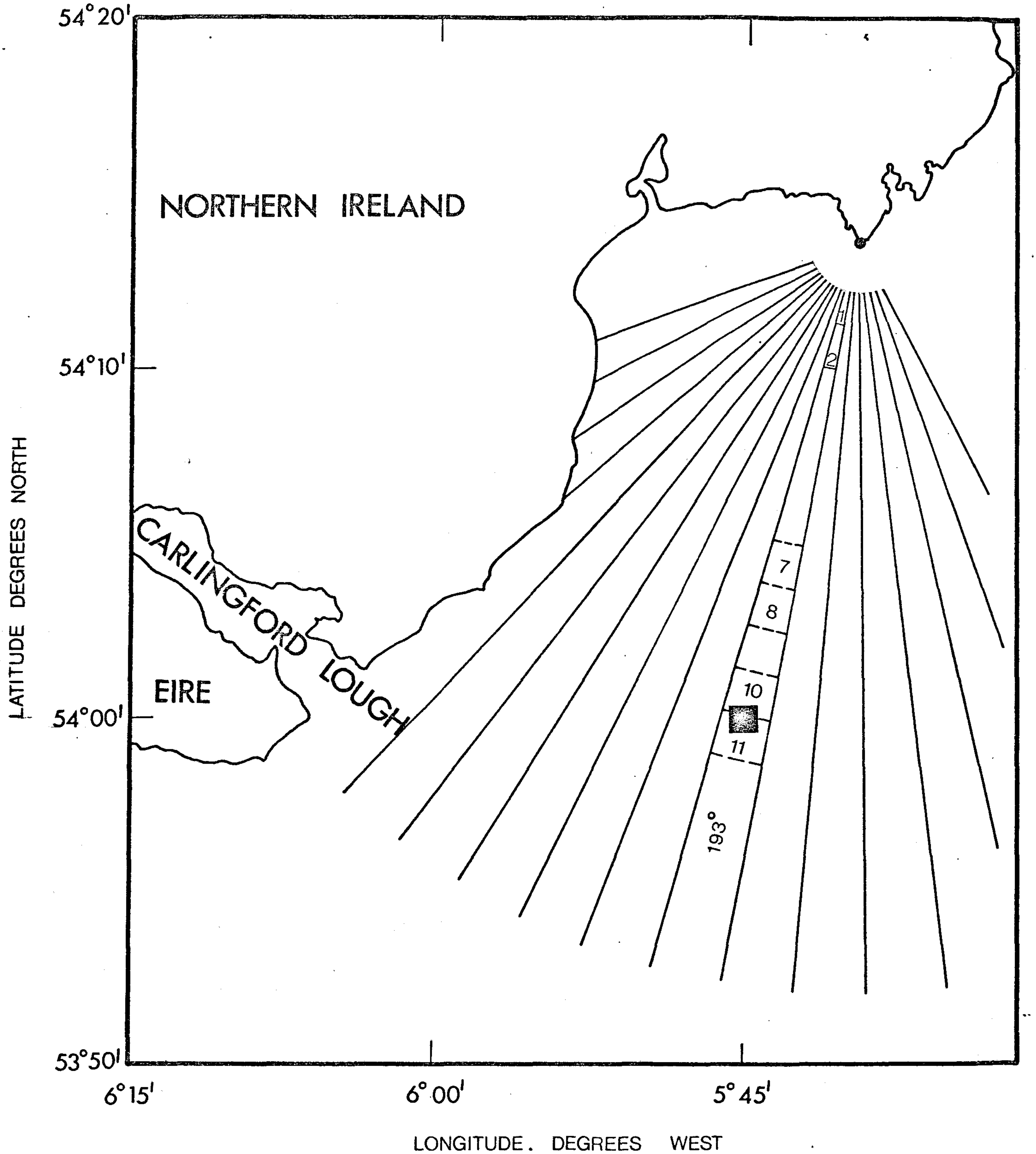


Fig. 1 Intercomparison site. (Black shaded area)

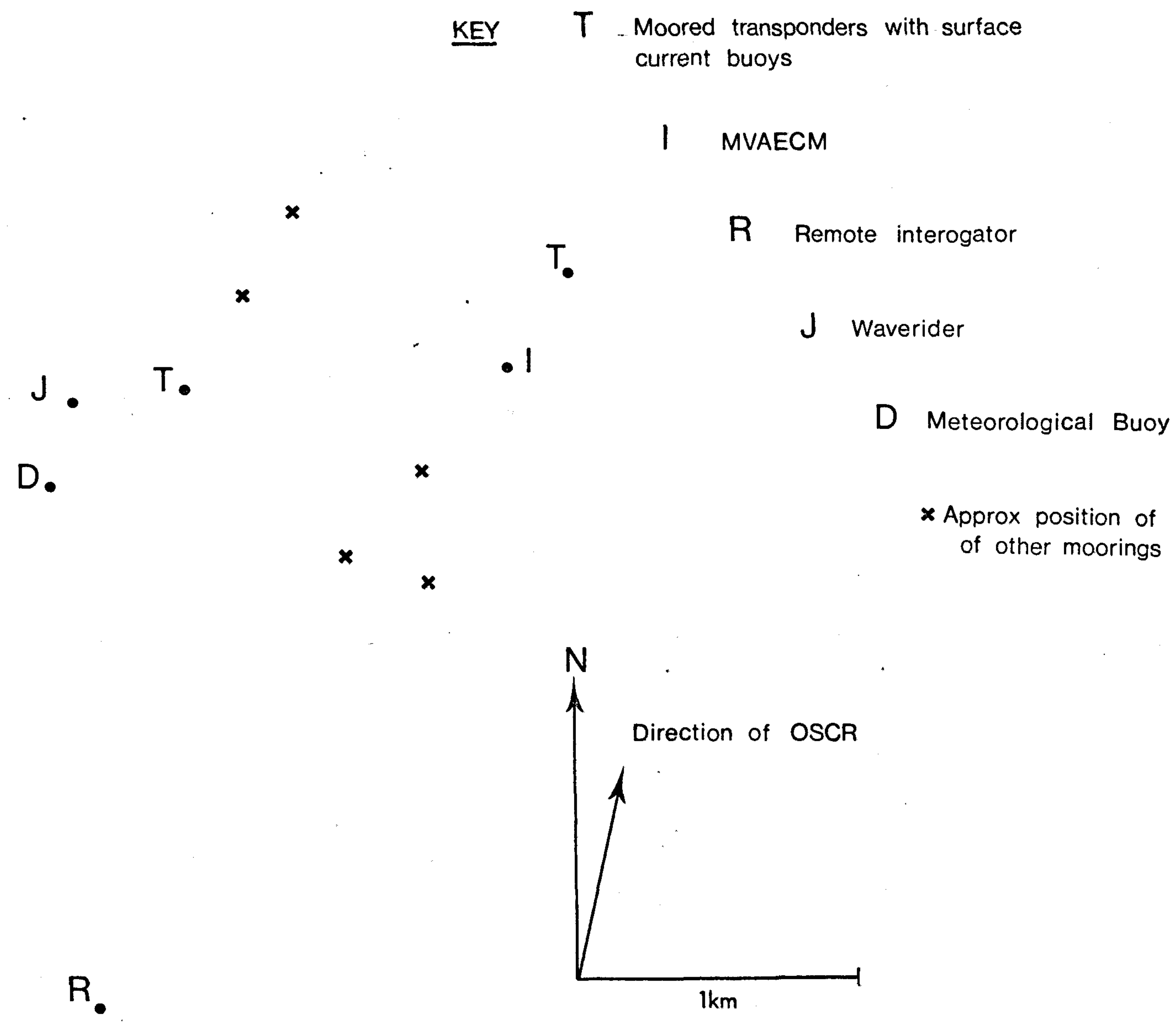


Fig.2 Disposition of moorings.

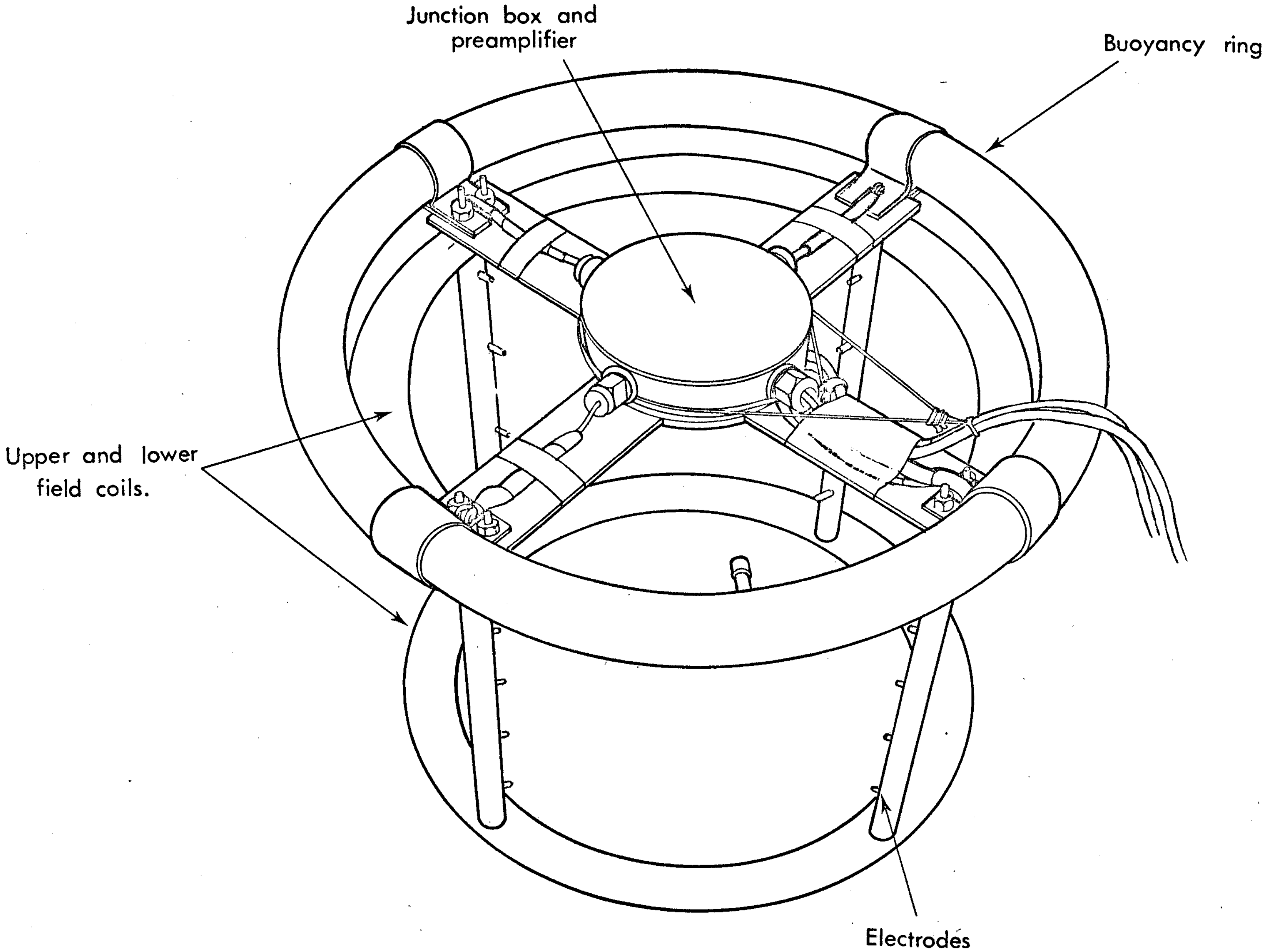
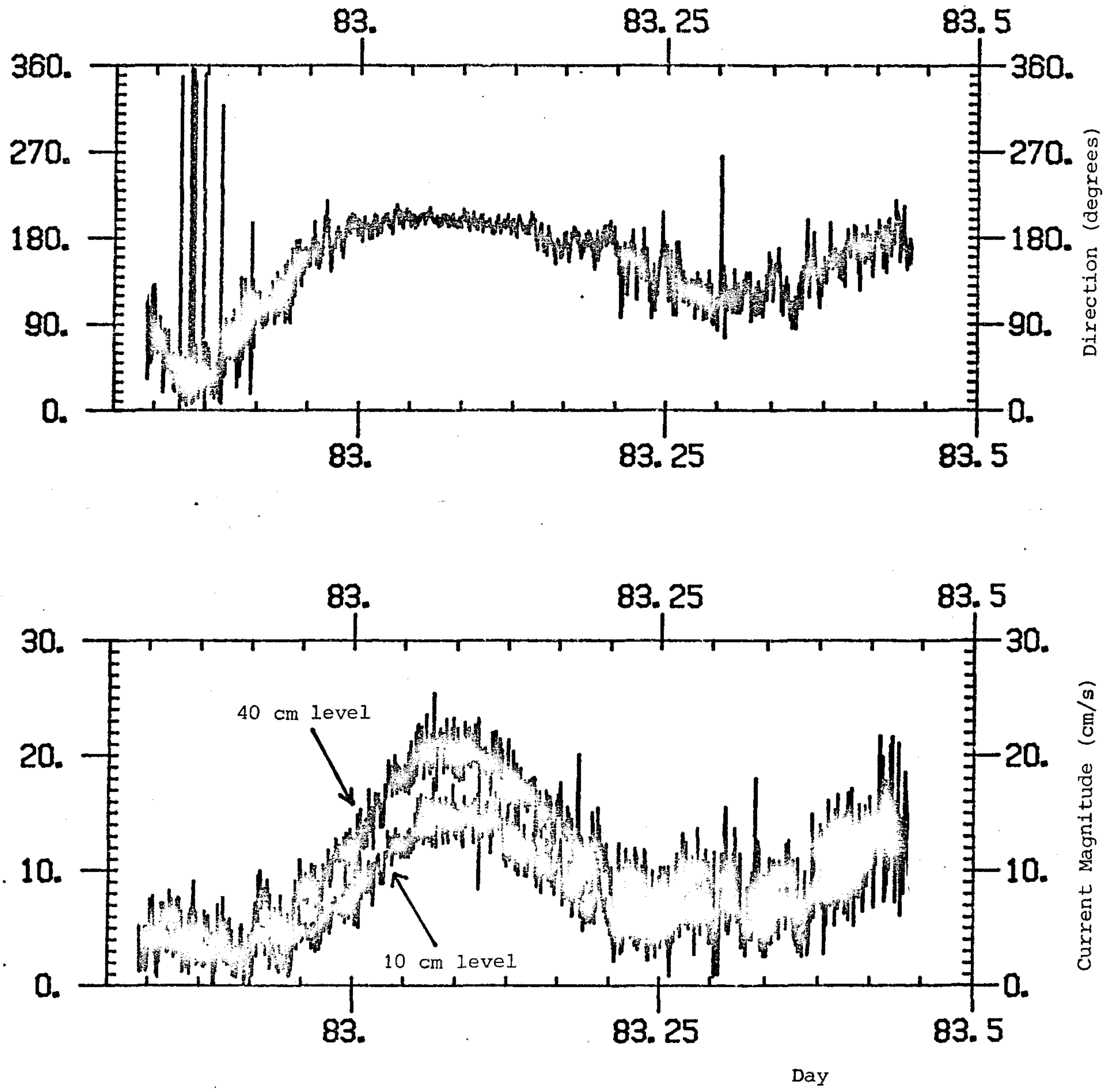


Fig.3 (a) MVAECM-Sensor head

Fig. 4 Time series plots of data from the MVAECM.
Levels 1 (10 cm depth) and 4 (40 cm depth).
Note very high coherence between levels in magnitude and directions.
Directions agree very well, but magnitudes show apparent shear.
(N.B. In this plot true current directions have been offset by 180^{O}).



Scale 1mm = 20mm
LENGTH ≈ 2·8m
WIDTH ≈ 1·5m

Fig.3 (b) MVAECM – Plan view

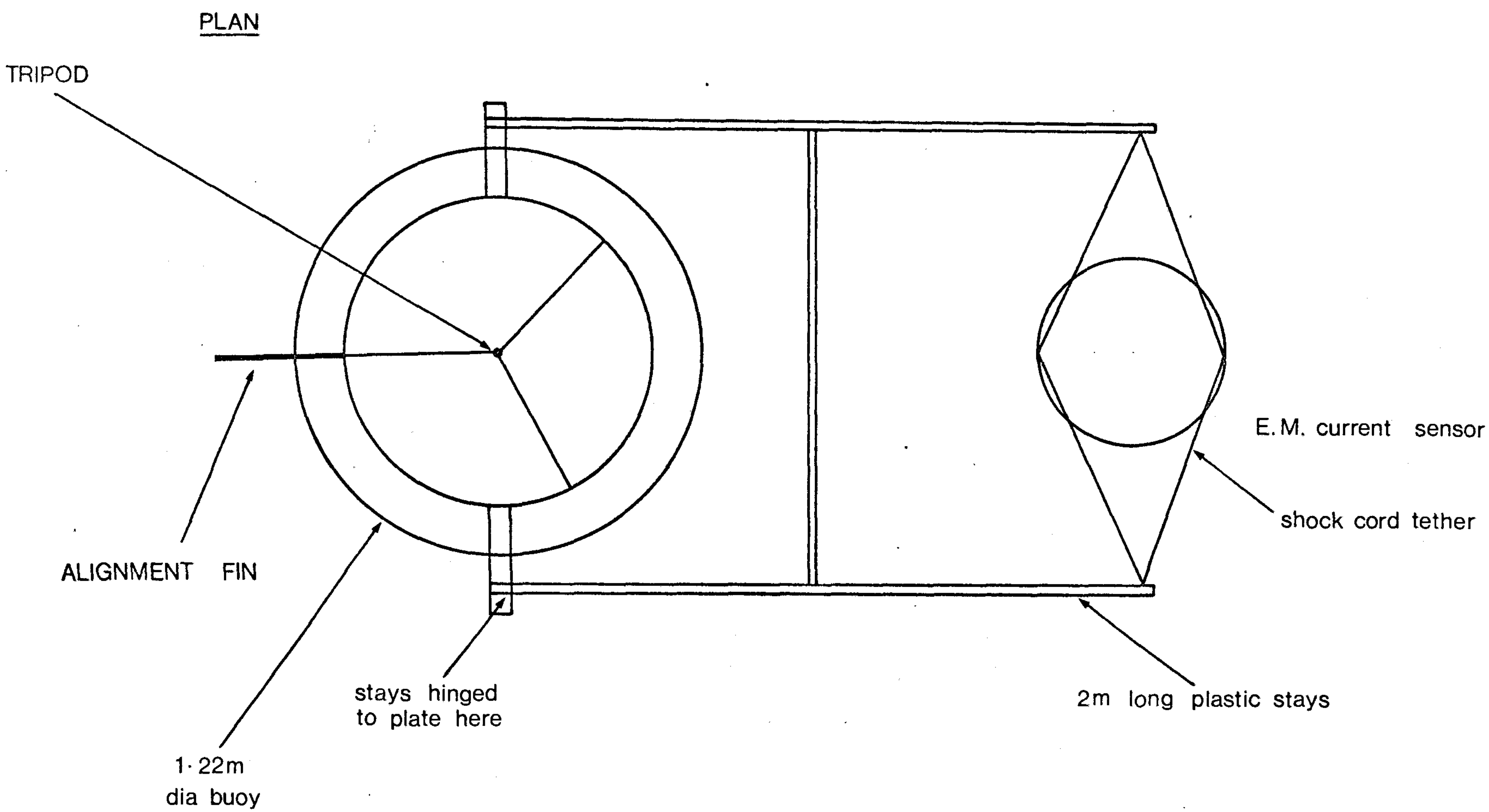
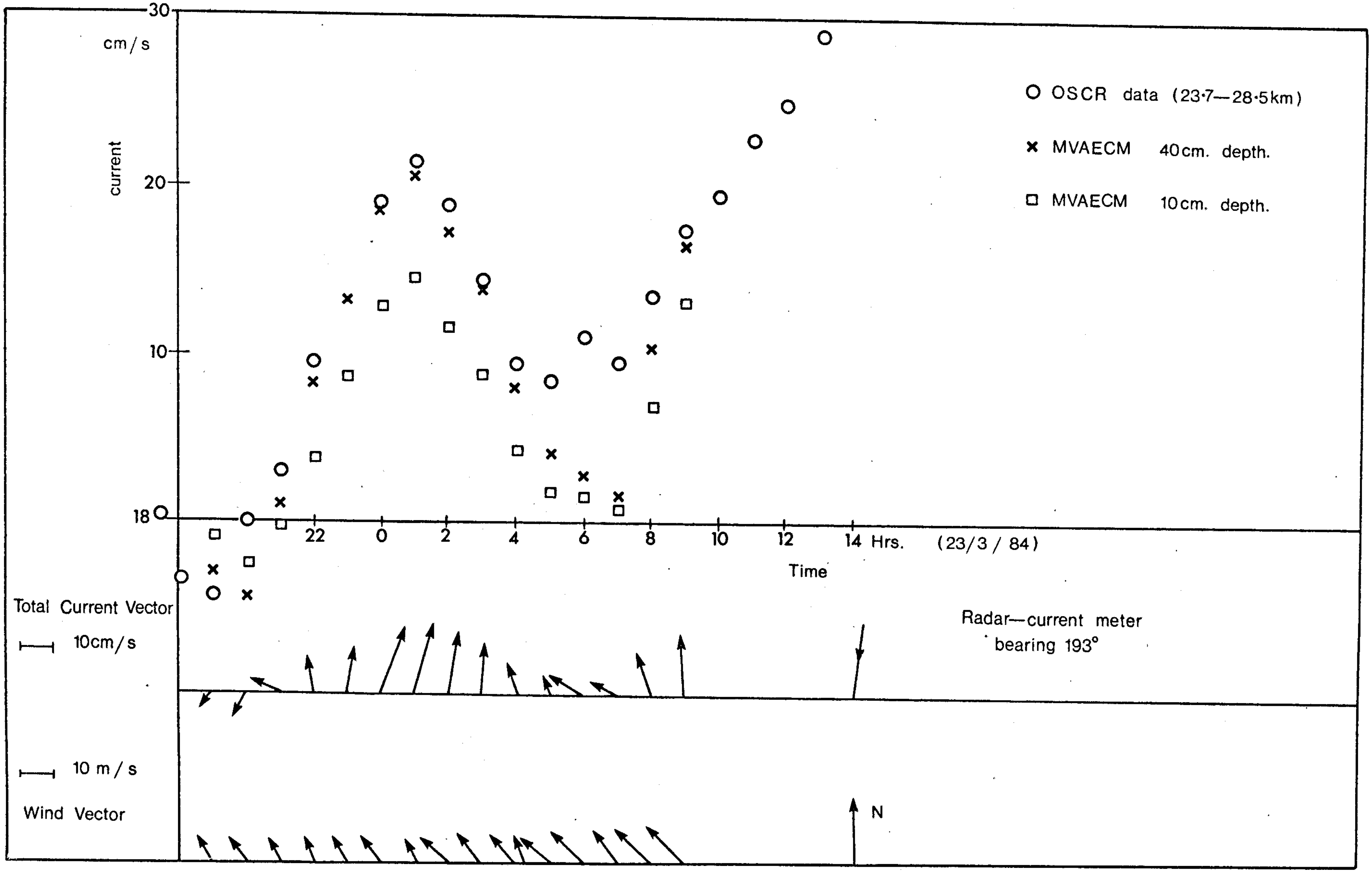


Fig. 5 Comparison of OSCR data with resolved component of current measured by surface current meter.



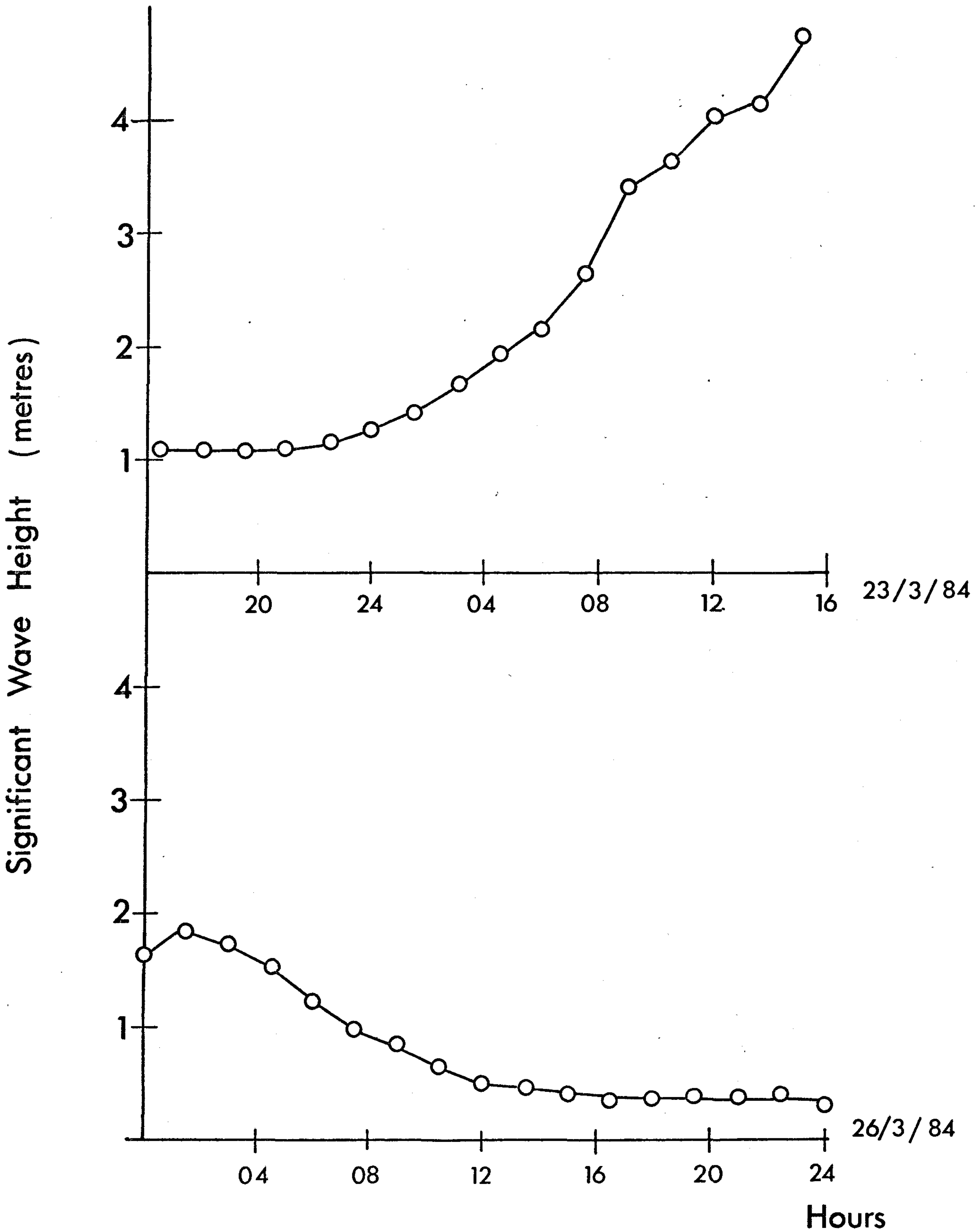


Fig. 6 Wave conditions during comparison periods - significant wave height.

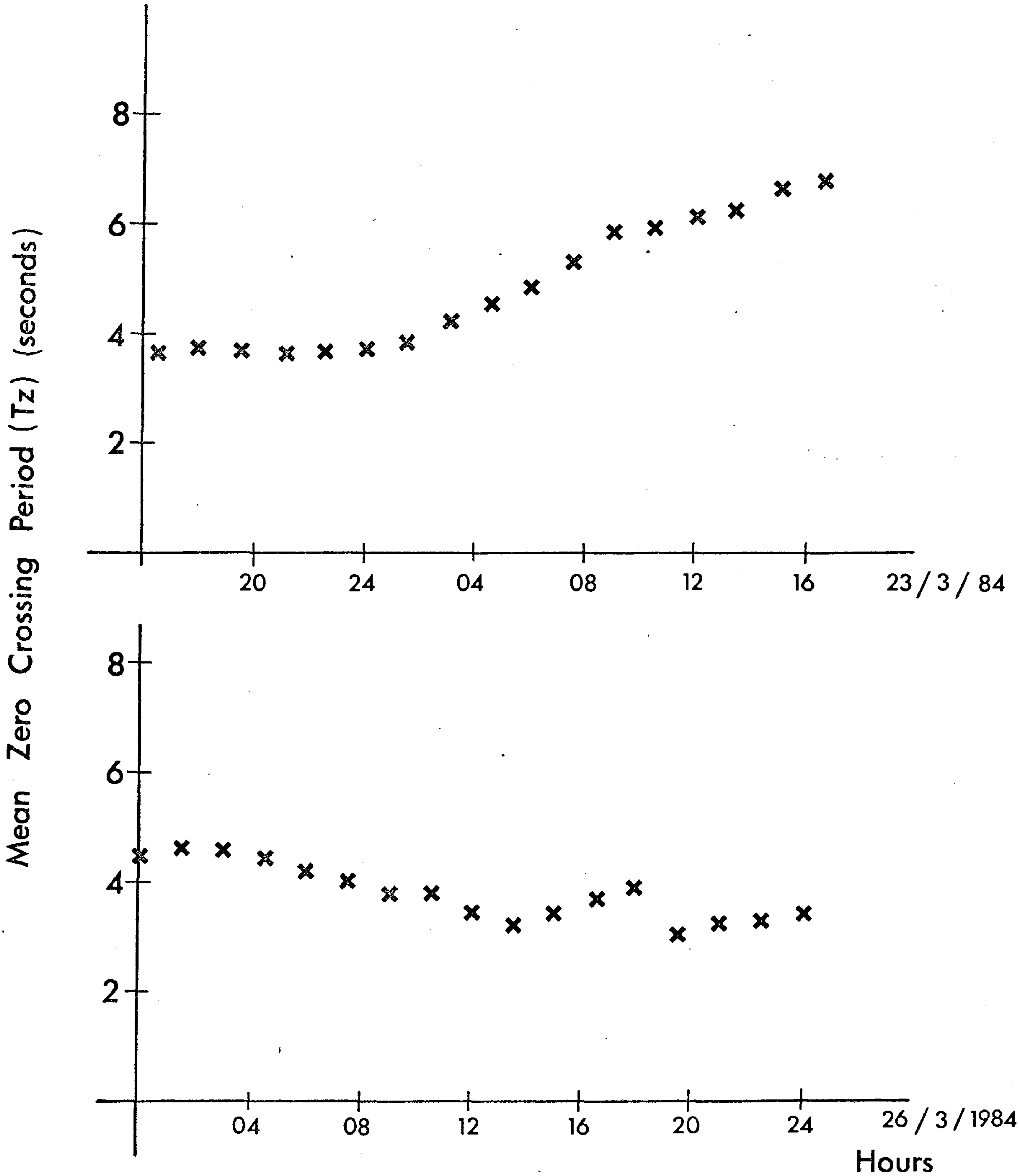
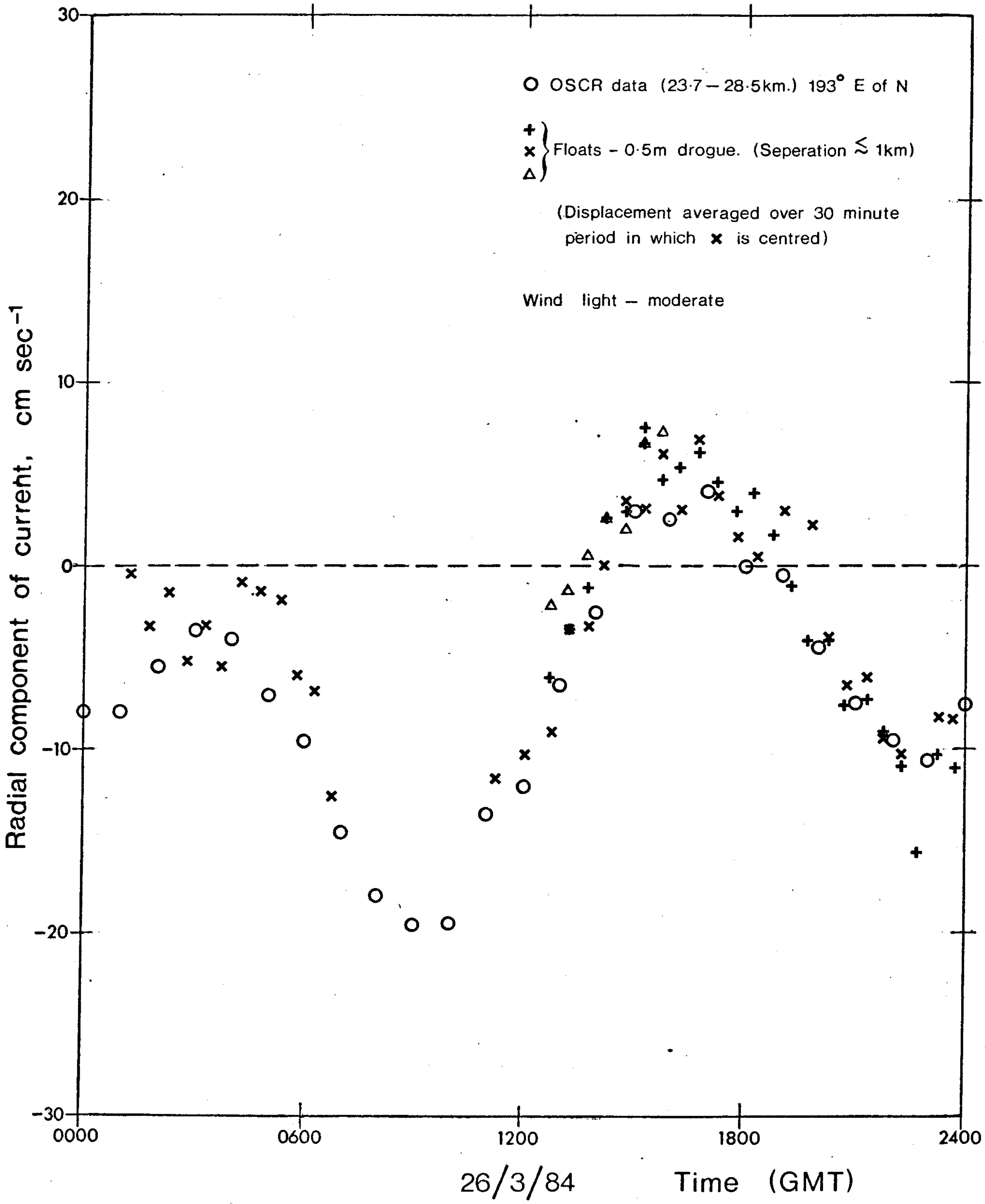


Fig. 7 Wave conditions during comparison periods
-mean period.

Fig.8 Comparison of OSCR data with resolved components of 0·5m. drogued float velocities.



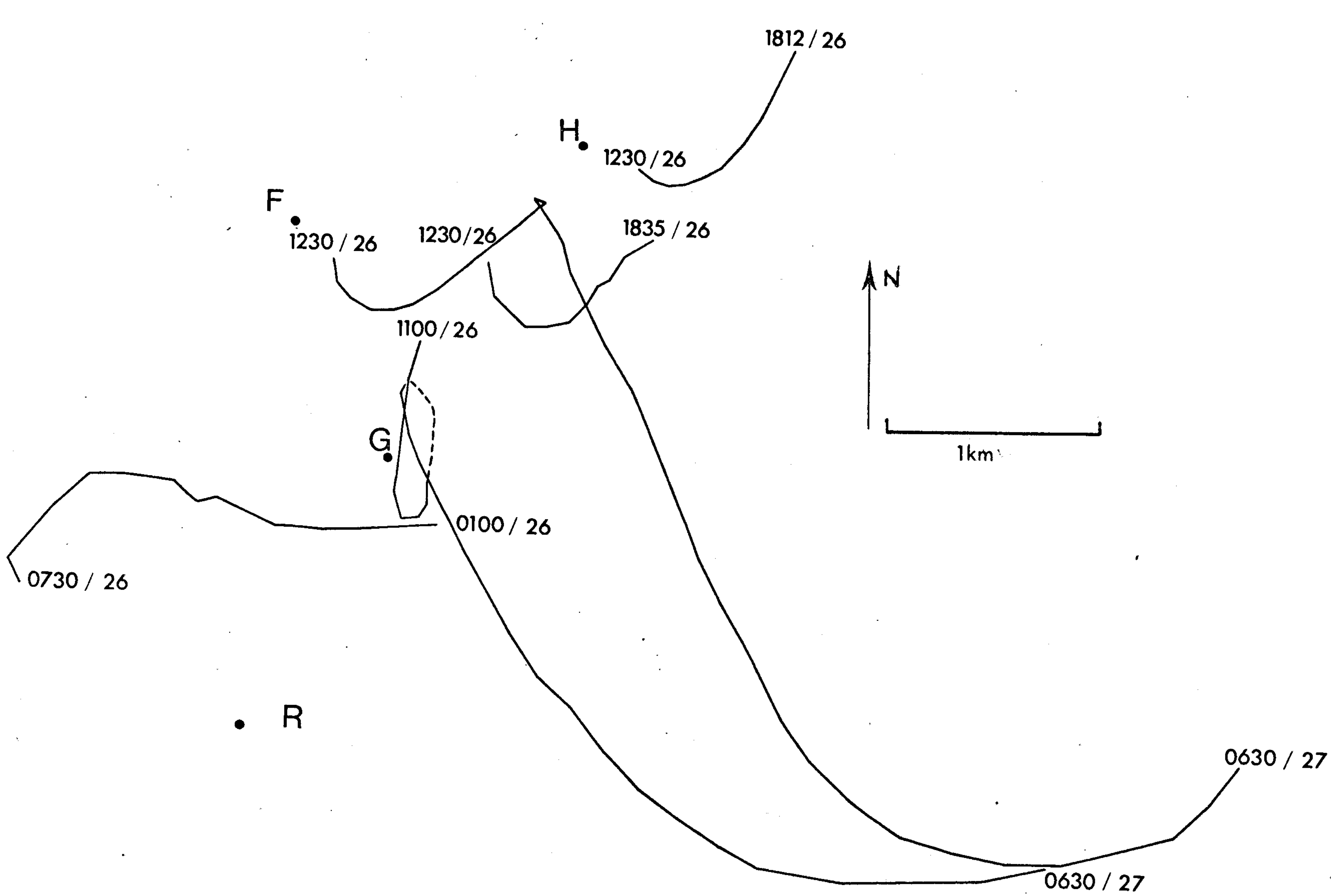


Fig.9 Float tracks during the period 0100 on 26th March - 0630 on 27th March (F. H. G. mark 3 transponder positions) R is the remote interogator.